NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF: GP

April 5, 1971

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures contained in the Code GP to Code USI memorandum on this subject, dated June 8, 1970, the attached NASA-owned U.S. patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No.	:	3,415,643
Corporate Source	:	Lewis Research Center
Supplementary Corporate Source	:	
NASA Patent Case No.	:	XLE-03629

Gayle Parker

Enclosure:
Copy of Patent

N71 23248
(ACCESSION NUMBER) (THRU)
2
(PAGES)
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(CODE)
(NASA CR OR TMX OR AD NUMBER)
17
(CATEGORY)

FACILITY FORM 602

NASA-HQ

United States Patent Office

3,415,643
Patented Dec. 10, 1968

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3,415,643
HIGH TEMPERATURE FERROMAGNETIC COBALT-BASE ALLOY

John C. Freche, Fairview Park, Richard L. Ashbrook, Berea, Gary D. Sandrock, Cleveland, and Robert Lewis Dreshfield, Parma Heights, Ohio, assignors to the United States of America as represented by the Administrator of the National Aeronautics and Space Administration

No Drawing. Filed May 31, 1966, Ser. No. 554,950
9 Claims. (Cl. 75—170)

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to improved alloys having high strength at temperatures up to 1500° F. while exhibiting high magnetic induction at low applied fields. The invention is particularly concerned with providing improved materials for use in electrical power generating equipment that is subjected to the environment of liquid metal vapor or to the vacuum of space.

Present day aerospace vehicles require space power systems having high efficiency. In order to increase the efficiency of a space power system, it is necessary to decrease the amount of power expended on cooling generators and motors. This can be accomplished by using rotor materials that have high Curie temperatures, high magnetic induction for low applied fields, and high strength at high temperatures thereby accommodating high operating temperatures.

Commercially available materials for space power system rotors include steels, such as AISI 4340, and high strength tool steel, such as H–11. Each of these steels has certain limitations. While at low temperatures, these materials have high magnetic induction for low applied fields. However, the strength of these steels falls off rapidly at about 1000° F.

One of the most desirable structural magnetic materials for use up to 1100° to 1150° F. is a cobalt-base alloy called Nivco. However, this material rapidly loses strength above 1200° F., and its magnetic induction falls off rapidly above 1300° F.

These problems have been solved by the present invention which provides a cobalt-base alloy for use as a material for rotors of electrical generators or motors to be operated at temperatures up to axxproximately 1400° F. These alloys can be either used as solid rotors or rolled and fabricated into laminated rotors.

It is, therefore, an object of the present invention to provide a ferromagnetic cobalt-base alloy having high strength at the elevated temperatures of liquid metal vapor in Rankine cycle turbine alternators.

Another object of the invention is to provide improved alloy materials having high Curie temperatures, high magnetic induction for low applied fields, and high strength at high temperatures, thereby permitting high operating temperatures for use in space power systems.

A still further object of the invention is to provide improved alloy materials for use in aerospace applications which are subjected to the environment of liquid metal vapor or to the hard vacuum of space.

These and other objects and advantages of the invention will be apparent from the specification which follows.

2

The present invention is embodied in alloys having the following nominal composition range:

Cobalt	From about 71.5 percent to about 94.3
Tungsten	From about 5 percent to about 14
Titanium	From about 0.3 percent to about 1.8
Zirconium	From about 0.1 percent to about 1.0
Carbon	From about 0.3 percent to about 0.7
Iron	From about 0 percent to about 10

A preferred embodiment of the invention includes alloys having the following nominal composition range:

Cobalt	From 82.9 percent to 87.9
Tungsten	From 7.5 percent to 10
Titanium	1
Zirconium	0.5
Carbon	0.6
Iron	From 2.5 percent to 5

An alloy composition used where high strength is of paramount importance has the following nominal composition:

	Percent
Cobalt	85.9
Tungsten	12.0
Titanium	1.0
Zirconium	0.5
Carbon	0.6

The subject alloys were prepared by vacuum induction melting. However, it is contemplated that these alloys can also be prepared by induction melting under a protective atmosphere of argon.

The subject alloys were prepared in a vacuum induction melting furnace capable of reaching pressures as low as 10^{-4} torr. and holding pressures as low as 5×10^{-3} torr. during active boiling of the melt. Raw materials were charged both into a zirconia crucible as well as into an "addition's-maker." After the crucible charge was melted, the melt was refined by permitting the oxygen in the charge to react with carbon to produce a so-called "carbon boil." After refining, the portion of the charge containing the reactive elements, titanium and zirconium, was added to the melt which was then heated to an appropriate casting temperature. The melt was then poured into ceramic shell molds heated to 1600° F.

Although vacuum induction melting was used in the development of this alloy series, similar alloys have been successfully induction melted under an argon atmosphere. These alloys are likewise amenable to melting by the electro-slag process where protection from the atmosphere is partially provided by a layer of slag rather than solely by vacuum or an inert gas.

The above listed alloys derive their high elevated temperature strength from the solid solution strengthening of cobalt by tungsten, by the precipitation of an intermediate phase of WCo_3, and by the presence of dispersed tungsten, titanium and zirconium carbides. The good magnetic and strength properties are the result of a compromise between the tungsten and iron content in the alloy. The iron contributes to the high induction and structural stability while the tungsten contributes to the high strength.

Various magnetic and mechanical properties of the preferred composition compared with those of one of the

strongest cobalt-base high temperature magnetic alloys commercially available are shown in Table I.

TABLE 1.—MAGNETIC AND MECHANICAL PROPERTIES OF SELECTED ALLOYS

Property	Test temperature, ° F.	Alloy			
		7.5W-2.5Fe	10W-5Fe	12 W	Nivco
Ultimate tensile strength, p.s.i.	1,300	57,200	58,000	59,000	[3] 95,000
	1,400	46,350	48,600	52,600	49,500
	1,500	41,000	49,000	50,000	[3] 29,000
	1,600	----------	----------	----------	22,000
	1,700	33,600	32,200	35,500	----------
Stress rupture life at stress of 45,000 p.s.i. in hours	1,200	[2] 50	90	[1] 1,268	750
	1,300	25	433	1,290	30
	1,400	1.2	96	392	1
Magnetic induction in kilogausses for field of 100 oersteds	1,400	10.3	9.2	8.2	9.4
Curie temperature, ° F.		[2] 1,820	1,710	1,690	1,690

[1] Stress 50,000 p.s.i.
[2] Extrapolated.
[3] Interpolated.

There are other alloys suitable for magnetic applications at elevated temperatures. Among these are H–11 and 18% nickel-maraging steel. However, their use is limited to temperatures below 1000° F. because of microstructural instabilities. The lowest test temperature shown in Table I is 1200° F.

It has also been found that the stress rupture properties of the alloy series can be improved by heat treating. Two such heat treatments have been found to improve the stress rupture properties of the alloy Co-7.5W-2.5Fe-1Ti-0.5Zr-0.6C in the range from 1200° to 1400° F. According to the invention, the alloy was heated for 72 hours at either 1700° F. or 1500° F. Table II illustrates the effect of such heat treatments on mechanical properties of the alloy as compared to Nivco 10.

TABLE II.—EFFECT OF HEAT TREATMENT ON MECHANICAL PROPERTIES OF SELECTED ALLOY

Property	Test temperature ° F.	Alloy			
		Co-7.5W-2.5Fe-1Ti-.5Zr-.6C			Nivco
		As-cast	Heat-treated—aging temperature		
			1,700° F.	1,500° F.	
Average ultimate tensile strength (p.s.i.)	1,200	55,800	53,400	53,300	----------
	1,300	57,200	51,500	51,100	95,000
	1,400	46,350	46,000	46,400	49,500
	1,500	41,100	42,300	----------	29,000
Average stress repture life at 45,000 p.s.i. in hours	1,200	[1] 50	2,500	----------	750
	1,300	25	400	1,700	30
Average stress rupture life at 40,000 p.s.i. in hours	1,400	25	30	300	0.4
Magnetic induction in kilogausses	1,400	10.3	10.3	----------	9.4

[1] Extrapolated.

The beneficial technical effect of heat treatment on stress rupture properties is associated with the formation of a finely dispersed precipitate in the material. The aging treatments do not significantly affect the tensile strength. Depending on the test conditions, both slight increases and slight decreases in tensile strength have been observed. However, the greatest room temperature ductility was obtained after aging at 1700° F. for 72 hours. Both heat treatments resulted in improved properties over the as cast condition and over the commercial alloy Nivco 10.

The examples set forth above describe the properties of castings made in accordance with the invention. It is contemplated that the cast alloys will be worked into sheet material by forging or rolling for use in making laminated structures, such as rotors, when it is desired to minimize eddy current losses. Conventional hot rolling techniques have been used to obtain sheet material for these alloys. A satisfactory annealing treatment for the sheet has been found to be one-half hour at 2350° F.

It is understood that equivalents or modifications of or substitutions for parts of the above-described embodiments of the invention may be made without departing from the spirit of the invention or the scope of the subjoined claims.

What is claimed is:

1. A cobalt base alloy having a high Curie temperature, high strength and high magnetic induction for low applied fields at elevated temperatures consisting essentially of from 5% to 14% tungsten, from .3% to 1.8% titanium, from 0.1% to 1% zirconium, from 0.3% to 0.7% carbon, up to 10% iron, and the rest essentially cobalt.

2. A cobalt base alloy having a high Curie temperature, high strength and high magnetic induction for low applied fields at elevated temperatures consisting essentially of 1.0% titanium, 0.5% zirconium, 0.6% carbon, from 7.5% to 10% tungsten, 2.5% to 5% iron, and the rest cobalt.

3. A cobalt base alloy as claimed in claim 2 containing 7.5% tungsten, 2.5% iron and about 87.9% cobalt.

4. A cobalt base alloy as claimed in claim 2 including 10% tungsten, 5% iron, and 82.9% cobalt.

5. A cobalt base alloy as claimed in claim 2 including 10% tungsten, 2.5% iron, and about 85.4% cobalt.

6. A cobalt base alloy consisting essentially of 12% tungsten, 1.0% titanium, 0.5% zirconium, 0.6% carbon, and about 85.9% cobalt.

7. A method of making a high strength ferromagnetic material having improved electrical properties at temperatures up to 1400° F. comprising the steps of

casting an alloy having a composition essentially in the range of about 5% to 14% tungsten, .3% to 1.8% titanium, 0.1% to 1% zirconium, 0.3% to 0.7% carbon, up to 10% iron, and the rest cobalt, and

heat treating the alloy to improve the strength thereof by aging for about 72 hours at a temperature in the range from about 1300° F. to about 1700° F.

8. A method of making a high strength ferromagnetic material as claimed in claim 7 including the step of working the cast alloy into sheet.

9. A method of making a high strength ferromagnetic material as claimed in claim 8 including the step of annealing the sheet at 2350° F. for one-half hour.

References Cited

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RICHARD O. DEAN, *Primary Examiner.*

U.S. Cl. X.R.

148—158, 12.7, 31.55, 2, 3, 32.5